butions from the pen of distinguished writers on commercial subjects and applied sciences. It will also be an illustrated cyclopædia of industrial news, inventions, and improvements, collected from Foreign and British sources, for the use of those concerned in raw materials, machinery, manufactures, building, and decoration. It will carry out what is greatly needed—a careful and systematic survey of the industrial activities of America, Germany, and France; in order to present such information, as it is useful for British practical men to obtain, at the earliest possible moment. Judging from the prospectus it seems calculated to serve a very excellent purpose, and we heartily wish it abundant success. We have also received the first number of a new sixpenny monthly entitled the *Workman's Magazine*, published by Messrs. Kent and Co., and edited by the Rev. Henry Solly, and chiefly devoted to articles connected with the social condition of the class whom it addresses. The editor, we think, might find a corner for science, the influences of which are now felt among all classes.

MR. WILLIAM STOKES, JUN., surgeon to the Richmond Hospital, has been elected to succeed Mr. Hargrave as Professor of Surgery to the Royal College of Surgeons, Dublin.

THE *British Medical Journal* understands that the University of Dublin, the King and Queen's College of Physicians, and the Royal College of Surgeons, have agreed upon a scheme for a joint examining board. The Queen's University, however, and the Apothecaries' Hall still stand aloof.

THE *Journal of Horticulture* says that a French farmer has discovered that the use of tan is an efficient preventive against potato disease. For three years he has introduced a small quantity of the residue of the bark used in tanning into each hole on planting his potato crop, and each time he has been completely successful in preserving his fields free from the annoying disease.

WE have received the catalogue of the mathematical and scientific works of the library of the late Mr. Babbage, which are in the hands of Messrs. Sotheby, Wilkinson, and Hodge. If not sold by private contract before February 1, 1873, they will then be sold by auction. The collection is one of rare value, and its dispersion would be an event much to be regretted. The catalogue fills 190 pages, and does great credit to the compiler.

THE *feuilleton* of the number for December 28, of the *Gazette Médicalè de Paris*, contains the concluding part of M. Dumas' admirable *éloge* on the late Isidore Geoffroy Saint-Hilaire.

WE learn from the *Engineer* that Mr. Eden, indoor engineer in the Edinburgh Telegraph office, has invented a system by which, with the existing instruments, it has been found practicable to send messages from both ends of a single wire simultaneously The invention has been tested between Edinburgh and Glasgow, and it has been found that one wire is capable of doing double work.

WE learn from *Ocean Highways* that considerable anxiety prevails in Sweden respecting the safety of the vessels attached to the expedition which were to have returned at the close of the navigable season. The brig *Gladan*, and steamer *Onkel Adam*, took out stores for the *Polhem*, and were to have returned before the winter set in. They are totally unprepared for wintering in the ice; and should they not be able to return, it will be necessary for the crews to abandon the vessels and take refuge in the *Polhem*, which in that case will be overcrowded, and crippled in her resources. The Norwegian Government has despatched to their relief the seal steamer *Albert*, which will make an energetic attempt to reach Spitzbergen. She takes out two wooden houses, to erect inshore at the most likely places for stragglers to find them, and abundant supplies.

TERRESTRIAL MAGNETISM *

I.

IN bringing before you this evening, gentlemen, the subject of terrestrial magnetism, it is not my intention to attempt to present you with an exhaustive paper on so wide a subject. It would be idle to pretend to give in a few short pages an adequate idea of all that has been ascertained on this subject, or even to present a satisfactory historical sketch of the progress made from earliest ages to the present time. Nor will I trouble you with a bare enumeration of the many facts, and methods, and theories that have gradually led scientific men to their present knowledge in this matter. But I will try rather to state, as clearly as I am able, what is the actual condition of our knowledge respecting the magnetism of the globe, and what the nature of its complex variations, without, however, entering much into details which, though they might perhaps be most convincing when reviewed at leisure, would be entirely out of place here, since they would only serve to encumber a paper intended for public perusal.

But, before treating of the special subject of terrestrial magnetism, allow me briefly to recall a few of the well-known properties of magnets.

That certain bodies possess the power of attracting iron was not unknown to the most ancient people; and men who had noticed this could not long have failed to observe the disturbing power that iron, in its turn, exerts upon the magnet when brought into its immediate neighbourhood.

But the duality of the magnetic force was doubtless a discovery of much more recent times, though now equally familiar as the former. That this twofold force ever seeks the opposite extremes, or poles, of a magnetic body, and that these poles, whilst possessing alike the power of attracting iron, are diametrically opposed in their action upon the poles of any other magnet, is expressed in the trite law that, "likes repel, and unlikes attract." Again, the law of magnetic intensity was unknown until the middle of last century, when it was found by Michell to be identical with that of universal gravitation, namely, to diminish inversely as the square of the distance of the body attracted. That this was not discovered at an earlier date is partly due to the complexity of the phenomena arising from the duality of the force, combined with the inseparable nature of the two energies. For, unlike electricity, to which in most other points it is so near akin, neither the positive nor the negative element of magnetism can ever exist alone in any body.

Now, since we know that magnets and iron act mutually upon each other, and that one magnet attracts or repels any other according to certain fixed laws, if we remove all disturbing bodies from the vicinity of a magnet, and leave it perfectly free to move by floating it on a liquid, or suspending it by a thread, we might expect to see the magnet remain at rest in whatever position we place it. But we perceive at once that this is not the case, and the magnet we thought to be free is found to be subject to a directive power, which forces it to take a fixed direction, without in the least interfering with the position of its centre of gravity. Disturb the magnet, and when it comes to rest it will again lie in the same direction as before. The earth, therefore, exerts a certain influence on the magnet, not producing any translation from one position to another, but only forcing the poles of the magnet to assume a definite direction. That this power possessed by the earth is precisely similar to that of an ordinary magnet, is easily shown by counteracting the earth's action by means of a magnet, placed at a suitable distance from the free magnetic needle, and with its marked end in the same direction as that of the needle, the latter will then rest in any position in which it is placed.

This polarity, or directive power of the earth, is said to have been known to the Chinese 1,000 years at least before the Christian era, and to have aided them in their long journeys across the trackless wastes of their vast empire. The use that has since been made of this simple fact, the growth of commerce, the spread of civilisation, and the thousand other blessings that it has brought to our very doors, need no long comment here. We may well marvel that such a source of wealth and prosperity was allowed by mankind to remain almost fruitless during such a long succession of ages.

The horizontal direction taken by the freely suspended needle is nearly north; but it generally deviates somewhat from the astronomical meridian. This deviation is termed the declination or variation of the compass. The existence of the declination was not unknown in remotest times, although its discovery is sometimes erroneously attributed to Christopher Columbus. To this great man we are, however, indebted for our knowledge of "the variation of the variation," since he was the first who noticed its change as he altered his geographic position in his great voyage of discovery across the Atlantic.

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* By the Rev. S. J. Perry, F.R.A.S., F.M.S., Director of the Stonyhurst Observatory. Extracted from the *Journal of the Liverpool Polytechnic Society*, by the permission of the Council. Communicated by the author.

The first and most important fact in terrestrial magnetism, viz., the declination or horizontal lie of the freely suspended magnet, being established, we may take an unmagnetised piece of iron, similar in weight and form to our magnet, and balancing it on an axis passed through its centre of gravity, allow it to rest on the extremities of this axis. We shall find that the unmagnetised needle will remain at rest in whatever position we choose to place it, since we have taken care to suspend it by its centre of gravity. But if we now substitute the magnetised instead of the unmagnetised needle, and place it in the plane of the horizontal magnet, we shall perceive at once that at whatever angle we place it on its supports it will invariably take up a definite position with respect to the horizon, the marked end, which points W. of N., dipping down until it stands in this country at an angle of about 70° to the horizon. The earth, therefore, not only tends to bring the magnetic needle into a certain azimuthal plane, but it also forces it to take a fixed position in that plane. The direction of the magnet is thus wholly determined by the earth's magnetic force.

Our next care will, therefore, naturally be to discover, if possible, what is the intensity of this terrestrial force which acts upon the needle. This might be determined by finding the resistance it is capable of overcoming, or the weight it will balance, the weight being attached to a thread wrapped round the axis of the needle. But the intensity of the earth's pull is more accurately found by a method similar to that which has been used with such success in observing the force of gravity at different points of the surface of the globe, in view of ascertaining the amount of its compression. A magnetic needle is suspended by a thread, from which all torsion has been removed, and then an oscillatory movement at right angles to the plane of minimum dip is imparted to the needle in such a manner as to leave the point of suspension at rest. The square of the time of a single oscillation is a sure measure of the intensity of the force producing the vibration, which in this case is the product of the magnetism of the needle by the horizontal component of the earth's magnetism. The factor due to the magnetic strength of the needle can be eliminated at once if the power of our needle is known, and the horizontal component of the terrestrial magnetism divided by the cosine of the dip of the needle will then give the required total intensity. But if the power of the magnet is unknown, and on account of slight but continual changes, it is always safest to consider it as doubtful within certain limits, the quotient of the earth's horizontal force by the magnet's power can easily be found by measuring the deflection of a free magnet produced by the attraction of the vibration needle at given distances. The result of these experiments is to place in evidence that the intensity of the earth's magnetism follows laws as constant as those of its directive force.

Having thus made ourselves acquainted with the three essential elements of the magnetism of our globe, viz., the dip and declination, which determine the direction, and the third, which expresses the intensity of the attracting force, our next step in the study of the earth's magnetism, as a whole, is to secure the most trustworthy observations of these three elements at as many different stations as possible. The instruments used must be of the most delicate description, as the differences to be measured are often excessively minute. For this purpose the needles are suspended by the slenderest thread of unspun silk, or the smoothest axis rests on knife edges of polished agate. The care with which the observations have to be taken may be judged of from the fact that, to obtain the time of a single vibration of the needle, twelve sets of 100 or 200 vibrations are taken, and each estimated to the twentieth of a second; or, again, for a single observation of the dip, the needle, which is balanced by the maker with scrupulous care, is so far suspected that readings are taken of each end, the needle is turned on its Ys, the whole instrument is reversed, and finally the poles are altered, and each of these readings repeated at least twice before the observer has satisfied himself that all necessary caution has been taken to secure a perfect observation. An apparatus of greater delicacy than those in general use has lately been invented by Dr. Joule, of Manchester, which we may hope will furnish results of still greater accuracy than those already obtained.

'Twas not until towards the middle of the sixteenth century that accurate determination of any of the magnetic elements were attempted; but since that time the declination has continued to be observed with some regularity, and before the end of the seventeenth century Halley had already made two long voyages to observe this element at different parts of the globe.

The dip, whose discovery is due to Norman, was first observed in 1576, but it does not seem to have attracted much attention until two centuries later.

The determination of the intensity, by means of the vibrations of a magnet, was first suggested in the last century by Graham, and the first maps of the isodynamics, or curves of equal intensity, are the fruits of the labour of General Sir Edward Sabine, who is now devoting the declining years of his life to the publication of the results of his life-long study of terrestrial magnetism.

From the above observations of the three magnetic elements, taken at different positions on the surface of the globe, the first general conclusion we are able to draw is one of no little importance. For, starting from any point of the earth, and following the direction of the horizontal needle, we are invariably led to one or other of two points, situated respectively in the Northern and Southern hemispheres. The entire globe is, therefore, traversed from N. to S. by a system of magnetic lines, all meeting in the same two points, resembling in this respect our geographical meridians and poles, and therefore termed the magnetic meridians and the magnetic poles of the earth. Our second conclusion is of scarcely inferior importance to the first. For if, instead of following the direction of the horizontal needle, we carefully observe the dip, and travel along the line, where we find the inclination invariable, we shall always be led, not up to a magnetic pole, but in a more or less circular path around the pole. These curves of equal dip, generally called isoclinals, bear a close resemblance to our geographic parallels of latitude; and as the geographic latitude varies from zero at the equator to 90° at the poles, so in like manner the dipping needle, which is horizontal at the magnetic equator, gradually increases its inclination until it becomes vertical at the magnetic poles.

From these angles of position of the dipping needle we can conclude at once that the horizontal component of the earth's magnetism must be zero at the poles, and probably maximum at the magnetic equator, where the terrestrial force is wholly horizontal.

We may, therefore, describe the magnetic poles in the words of the Astronomer Royal, "as the common points for the convergence of magnetic meridians, for the verticality of the dip, and for the evanescence of the horizontal force."

But there are other points on the earth's surface which merit our most special attention. I will not call them poles, as they have little in common with the two poles of which we have just been speaking, but I will describe them as points of maximum intensity. The isodynamics, or lines of equal intensity, are not found to follow such simple laws of distribution as the meridians and the lines of equal dip and horizontal force, though these latter are far from being arranged with the same regularity as the meridians and parallels of latitude of a geographic globe. None of the magnetic curves are perfect circles, the poles are not coincident with the geographic poles, nor are they opposite to each other, one being situated north of Baffin's Bay, and the other in South Victoria, but still there is a general approach to regularity in the magnetic lines, if we except the isodynamics, and the law of variation of the dip was found to be fairly represented by the formula, tan. $\delta = 2.$ tan. L (the magnetic latitude), a law discovered by Krafft in 1809. The greatest departure from the general regularity of the curves we have been mostly considering, is the indication of a second pole in the Southern Hemisphere from the peculiar distribution of the lines of equal horizontal force. But in the case of the isodynamics we find three well-marked points of maximum intensity, one N.W. of Hudson's Bay, another in Siberia, and the third not far from the South magnetic pole in Victoria. Besides these there are also two maxima of small intensity, one situated slightly north, and the other at about 15° S. latitude. We are still, however, able to trace a rough approximation to a law in the change of the intensity, the value at the principal maximum being about double what is found to be on the curve of minimum intensity.

The distinction between points of maximum intensity and the true magnetic poles has not always been attended to with sufficient care, and this is partly to be accounted for by the considerable and often preponderating influence of these maximum points on the several magnetic elements. A consequent doubt was for a long time entertained respecting the number of the magnetic poles. Halley, from a careful study of an extensive series of declination observations, made partly by himself in 1698-9, was led to the conclusion that the earth has four magnetic poles. The same opinion has been most ably advocated within our own days by Prof. Hansteen of Christiana, who had previously collected together a vast mass of observations of the declination, dip, and horizontal force. But the interesting series of results which Hansteen has brought forward in support of his view, are most readily explained by the evident changes that have taken place in the magnetic state of the region of maximum intensity situated in Siberia, where Hansteen himself specially observed. The Northern regions, where the magnetic force is greatest, abound in ferruginous strata, and there too the intensity of the cold far exceeds anything that is experienced in other lands on the same parallel of latitude. These regions may therefore not only be charged with a most abundant supply of permanent magnetism, but they may also be affected to a very considerable degree by atmospheric changes, and by those electric currents that are continually passing to and fro in the upper crust of the earth, and are doubtless producing very important changes in the subpermanent magnetism of certain layers of softer ferruginous matter. Whatever may be the nature of terrestrial magnetism, we cannot ignore the great influence exercised on its distribution by what may be termed local magnetism, the magnetism of volcanic formations, of mountain chains, of ferruginous beds; some harder than others and therefore less subject to magnetic influence, but retaining its effects the longer; some more affected by the extremes of heat and cold, and hence exposed to more rapid and radical changes in their magnetic condition.

But the question of the number of magnetic poles is leading us to another point of scarcely less importance, viz., the investigation of the changes that take place in the magnetism of the globe. The first point of inquiry is whether terrestrial magnetism as a whole is subject to continual change, and if so, are these changes periodical? Do they move in cycles? Do they follow any fixed laws that may lead to a knowledge of their causes?

The difficulty in answering these questions arises mainly from the irregular distribution of the points of maximum intensity; but, granting that we meet with numerous exceptional cases, which no doubt will finally be discovered to depend on local influences, we can trace a very regular and periodic change in all the magnetic elements.

The first accurate observations that have come down to us are those of the declination, or variation of the compass, taken in Paris in 1541, when the needle pointed 8° to the east of the astronomical meridian. From that period the easternly deviations gradually increased, until it attained a maximum value of 11° 30′ in 1580, when it returned slowly on its path and vanished in the year 1660, Paris being then on the curve of "no variation." Pursuing its westernly course, the needle pointed more and more west of north each year, and only reached its greatest western elongation of about 23° in 1814. The needle is at present returning towards the east, at the yearly rate of about 9′·5, and actually points rather less than 17° west of north. The variations of the declination at London have followed much the same order as those at Paris, nor has there been any great difference in the extent.

The dip observations have unfortunately not been carried on so continuously during such a long series of years, and in consequence the secular variation of this element is less well determined than that of the declination. With the exception of a single observation by Norman in 1576, who found the inclination of the needle at London to be 71° 50′, we have scarcely any reliable data previous to 1720, when the dip had increased in London to 74° 42′. Since the latter epoch this element has always continued to decrease, being 70° 35′ in 1800, and now less than 68°, with an annual diminution of about 2′·5.

Of the secular variation of the intensity we know even less than of that of the dip, since the first observations date only as far back as the end of the last century; and we have no less an authority than that of Sir Edward Sabine for the statement, that "at commencement of the present century the bare fact of there being any difference whatsoever in the intensity of the magnetic force in different parts of the earth was unattested by a single published observation." The results, however, of modern research supply us with the important fact that the horizontal component of the intensity is at present rapidly increasing, its yearly rate of change being one 600th of its total value.

Now each and all of these gradual variations in the several elements of the earth's magnetism force upon us the conclusion that the magnetic pole must be endued with a motion of rotation in a more or less circular path around the pole of the earth's axis. The results of such a rotation apparent to an observer situated for example in England will be easily understood if we consider for a moment the similar movement of any of the inferior planets in its orbit round the sun as viewed from the earth. Take Venus, for instance, which is the most conspicuous of the planets. At one time it may be seen moving away from the sun towards the east, when it is called the evening star, since i sets later than the sun. This outward movement continues for a time, until the planet reaches the point of its maximum elongation; it then returns towards the sun, and after a time becomes lost to sight in the brilliancy of the solar rays, or on very rare occasions is visible in transit over the solar disc, as it will be for the first time this century in 1874, and again in 1882. Having passed the sun, Venus becomes the morning star, rising earlier and earlier until it has attained its greatest western elongation, when it again returns towards the sun. An analogous movement of the magnetic pole around the geographic pole has been clearly indicated by the secular variations of the declination, dip, and horizontal force. At the middle of the 16th century the bearings of the needle which would lead us to the magnetic pole were some 10° east of north. As time went on this deviation diminished, whilst the dip increased, showing that the magnetic pole was approaching us, as it got nearer and nearer to the meridian. About the middle of the 17th century, or rather somewhat later, the magnetic pole crossed our meridian, which thus for the moment partly coincided with the "line of no variation." From that time the needle has always pointed west, the western declination increasing more and more until the pole reached its maximum elongation in 1815. During this period there was a gradual decrease in the dip, manifesting a recession of the pole, and this has continued steadily, though with diminished acceleration, ever since the needle commenced its backward journey towards the geographic meridian. The present secular increase of the horizontal force also shows that the pole is receding, and that it will cross our meridian next on the further side of the geographic pole. This will take place, according to the calculation of M. Quetelet, director of the Brussels Observatory, about the year 1940, and thus a complete revolution of the magnetic pole will occupy a period of some 560 years. Other physicists make this period longer. Local magnetism must of course interfere greatly with the position of the pole, and with its velocity of revolution, but this disturbing cause will affect still more the movements or form of the "curve of no variation."

This rotation of the magnetic pole round the extremity of the earth's axis bears so striking a resemblance to the motion of the pole of the heavens round the ecliptic, that we are led at once to inquire if anything can be detected in the magnetic rotation that corresponds with the inequalities in the precession of the earth's axis, with the nutation caused by the action of the sun and moon. Are there, in other words, any annual, semi-annual, or monthly inequalities? The observations of the declination, taken during a series of years, and grouped together according to months, led to a variety of conclusions respecting the influence of the sun on the deflection of the needle. Arago agreed with Cassini in placing the sun in the vernal equinox at the maximum western variation, and in the summer solstice at the minimum; whilst Bowditch, in America, and Beaufoy, in England, both found that a maximum occurred in August and a minimum in December, though a second maximum and minimum were placed by each in different seasons. The fact of some yearly range of the needle about its mean position appeared to be established; but local influence seemed to have a large share in determining the nature of the annual curve.

(To be continued.)

SCIENTIFIC SERIALS

THE *Geological Magazine* for December (No. 102) opens with a description by Mr. James Cartro of a new genus and species of fossil crustacea from the Upper Greensand of Lyme Regis, which the author proposes to name *Orithopsis Bonneyi*. The